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TEMNOCHILA VIRESCENS AND ENOCLERUS SPHEGEUS IN RELATION TO THE MOUNTAIN PINE BEETLE IN SUGAR PINE

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by
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Berkeley, California
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Forest Insect Laboratory
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Temnochila virescens and *Enoclerus sphegeus* in relation to the mountain pine beetle in sugar pine

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T A B L E   O F   C O N T E N T S

<u>TEMNOCHILA</u> <u>VIRESCENS</u> AND <u>ENOCLERUS</u> <u>SPHEGEUS</u> IN RELATION TO THE MOUNTAIN PINE BEETLE IN SUGAR PINE

Preliminary Report

INTRODUCTION

The blue-green trogositid, <u>Temnochila</u> <u>virescens</u> (Fabr.) var <u>chlorodia</u> Mann. and the red-bellied clerid, <u>Enoclerus</u> <u>sphegeus</u> Lec. are the most important native coleopterous predators of the mountain pine beetle, <u>Dendroctonus</u> <u>monticolae</u> Hopk. in sugar pine. The mountain pine beetle is believed to be held in partial check by these two species in addition to a few other predators of lesser importance. Strong evidence of this fact is indicated by observations by forest entomologists carried over a period of years. Parasites, on the other hand, are of relatively small importance in the control of the mountain pine beetle in sugar pine stands because of the thick bark which does not readily permit oviposition.

There has long been a need for studies on the predators of the mountain pine beetle, and especially on these two species, to determine just how important they are as a factor in biological control. A considerable amount of information on the seasonal history and habits of <u>Temnochila</u> was obtained by Person* during 1923 and 1926 in relation to the western pine beetle, <u>Dendroctonus</u> <u>brevicomis</u> Lec. in ponderosa pine. Practically nothing was learned with regard to biological control. <u>Enoclerus</u> <u>sphegeus</u> has long been known by forest intomologists and has been assumed to carry a leading role in the control of the mountain pine beetle because of its close association with it; yet so little is known about it, even of its seasonal history, that such an assumption is not justified. Studies of both species, because of their constant association with the mountain pine beetle in sugar pine stands, should yield basic information on the biological control of this important forest insect.

A preliminary investigation of <u>Temnochila</u> and <u>Enoclerus</u> was started during May, 1937 and carried until the 1st of October. A large amount of information on the relative abundance of each species with different seasonal broods of the mountain pine beetle was obtained. The seasonal history and habits of <u>E.</u> <u>sphegeus</u> were carefully investigated, while substantiating data were obtained on the seasonal cycle of <u>Temnochila</u>. In addition some experiments were undertaken to study the importance of each predator as a

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*Person, H. L. A Study of the Predaceous Enemies of the Western Forest Scolytids - Preliminary Report - 1923.

A Study of the Clerid, <u>Thanasimus</u> <u>nigriventris</u> Lec. with Notes on Other Enemies of the Western Pine Beetle. Stanford Univ., California, May 8, 1928.

control factor. The field base for these studies was located near Wawona, California at an elevation of 5,500 feet. Control of an aggressive mountain pine beetle attack in mature sugar pines in a virgin stand of timber at Mariposa Grove in Yosemite by CCC crews provided the means for obtaining much of the field data and experimental material, from overwintering infestations. An additional amount of information was obtained on summer brood trees in an aggressive attack on second growth sugar pine stands in the vicinity of Signal Peak on the Sierra National Forest.

QUANTITATIVE ABUNDANCE

Information on the number of each predator found beneath the bark of trees infested by the mountain pine beetle was obtained from 30 trees; 15 of them containing overwintering broods and 15 containing summer broods. A sample from each tree included from 14 to 40 square feet of bark area in the most heavily infested portion of the bole, where mountain pine beetle broods had advanced to the mature larval and pupal stages. Counts were made on each predator lying on the inner bark and sapwood surfaces without seeking whatever number may have been hidden away in the bark. In addition, sample brood counts of the mountain pine beetle considered average for each infested tree were made on two square feet of bark area, taken from each tree. Following is a summary of analyses:

Total bark area in square feet analyzed for predators	827.2
Total bark area in square feet analyzed for D.m. broods	42.0
Average D.m. brood per sq. ft. in overwinter trees	104.2
Average D.m. brood per sq. ft. in summer trees	66.4

Table 1.
Number of D. *monticolae* and Predators per Square Foot in Infested Overwintering 1936-1937 and Summer 1937 Trees.

Overwinter 1936-1937

Tree No.	Date 1937	D.m. brood: total	T.v.s. larvae	T.v.s. adults	E. sphegeus larvae	Other clerid larvae	Area sampled for predators. Square feet.
5	6/8	120.5	0	1.25	1.00	0	21.6
8	6/15	148.5	0	.37	.43	1.56	16.0
10	6/23	83.0	0	.52	.63	1.05	19.0
12	6/29	75.0	0	.11	.79	1.12	26.6
14	7/7	90.0	0	.94	.10	.63	19.0
16	7/12	91.0	0	.23	2.29	.76	14.0
18	7/13	84.0	.07	.28	2.21	0	14.0

Summer 1937

Tree No.	Date 1937	D.m. brood total	T.v.c. larvae	T.v.c. adults	E. sphegeus larvae	Other clerid larvae	Area sampled for predators. Square feet.
8	8/19	105.0	.80	.36	.03	.40	27.2
9	8/17	18.0	.17	.15	.02	.07	40.0
10	8/18	5.5	.19	0	.06	.19	15.3
13	8/17	45.5	1.22	.14	.14	.03	28.8
23	7/20	126.5	.10	.15	.30	.05	20.0
27	8/23	150.0	2.84	.14	0	.38	20.8
28	8/4		.71	.33	.33	0	18.2

The data included in this table are from trees which represent best the average condition of brood and predators found in overwintering and summer trees. These figures are graphically illustrated in Figure 2.

Certain significant points follow as a result of these analyses. They are enumerated in order of importance.

1. Almost complete absence of T.v.c. larvae was noted on overwintering broods; only one fully grown specimen was found in all trees analyzed. The reason is difficult to explain in view of the comparative abundance of T.v.c. adults, not only on overwintering trees in the spring, but also on trees containing young D.m. broods in the fall.

2. Enoclerus sphegeus larvae were rarely found on the summer generation trees containing D. monticolae broods. This is not surprising in view of the scarcity of adults present at the time the summer broods of the mountain pine beetle were established.

3. In comparing the importance of the two predators, as judged by their prevalence, E. sphegeus is most important on overwintering broods and T.v.c. most important on summer broods.

4. Other clerid larvae found were of doubtful identity, probably Thanasimus undulatus V.D., especially those found with overwintering broods. Some may have been young E. sphegeus larvae which were undernourished. The clerid larvae found with summer broods were nearly all Thanasimus lecontei.

5. The numbers of E. sphegeus and T.v.c. larvae found with overwintering broods of D. monticolae did not appear to be large enough to be much of a control factor, as judged by the heaviness of D.m. broods. This may explain in part the reason for an apparent build up in infestations found locally in certain sugar pine stands during the summer of 1937.

6. Little correlation seems to exist between the number of predators present per unit of bark area and the amount of mountain pine beetle broods.

This is perhaps due to too few predators, even where they are most abundant.

7. Further data of this nature carried over a number of seasons, are necessary before proper conclusions can be made on the relative importance of these two predators as a biological control factor against the mountain pine beetle.

SEASONAL HISTORY AND HABITS
(See Photographs)
<u>Temnochila</u> <u>virescens</u>

<u>Seasonal Cycle</u>

One seasonal generation is developed each year, under normal development conditions (Temperature Chart, Figure 1) and an abundance of available food. Eggs are laid on trees containing summer broods of the mountain pine beetle throughout the summer months, and these hatch out into larvae which complete development to pupae and adults during the late summer and autumn months. The new adults remain under the bark or emerge, but hibernate during the winter months. Those having emerged hibernate in bark crevices. Details of each development stage are presented.

<u>Eggs</u>. (Photograph 1.)

1. Description. Elongate, 2½ to 3 mm long, ½ mm wide; delicate shade of pink, some nearly white; ends pointed or rounded.

2. Location and number. They are deposited in tight bark cracks, under bark plates, or near <u>D. monticolae</u> ventilation holes, at all depths of bark from immediately above the phloem layer to just underlying the bark surface. When extended fully the ovipositor of the female adult is ½ inch long, giving considerable latitude for placing the eggs. The eggs are deposited in groups varying in number. A total of 91 groups of eggs was examined, with an average of 7 eggs to the group. The largest number of eggs found in a single group was 33, the smallest was 1 egg.

3. Incubation period. Eggs hatch out in from 5 to 7 days at a constant temperature of 75° F. Under field conditions during the summer, from 7 to 14 days are required.

<u>Larvae</u>.

1. Development period. With a normal supply of host food material, under ordinary summer temperatures in their native habitat, the development period is 50 to 70 days before pupation. A much longer period of larval development is required where food material is scarce. Two larvae which were fed under controlled set up in the field were reared from newly hatched to the fully grown stage, one of them in 65 days and the other in 70 days. A third larva, which was periodically starved and fed, required 6 months to reach the fully grown stage.

2. Number of instars. Instars numbering 5 were traced on one individual larva from cast-off skins, in developing from the newly hatched

stage to the 3/4 grown stage. Two instars were traced on 3 other larvae in developing from the 3/4 grown to prepupal stage in the same manner. While this information is by no means conclusive, there are indicated at least 7 instars during the course of larval development.

Pupae:

Upon completion of the larval stage, pupal cells are excavated in the inner phloem layer next to the wood or at any point within the bark. These are made only large enough to accomodate the prepupal larva in a half-coiled position which it assumes before pupation. A rearing period of from 12 to 18 days ensues before pupation. The pupal period lasts from 18 to 30 days under summer field conditions. Actual records of the period were taken from 3 different specimens, one in the field which required 27 days, and 2 in the laboratory at Berkeley, one requiring 17 and the other 18 days at a temperature of 75° F. constant. Further records are necessary.

Adults.

1. Prevalence. Temnochila adults are most prevalent during the spring and summer months on infested trees, especially on those containing the younger stages of mountain pine beetle brood. They are not so numerous in the fall, but this is likely because of a number of the old adults have died and only a few new adults have emerged. Mating pairs are often found throughout this period.

2. Oviposition period. Eggs are laid throughout the period of adult life, following sexual maturity which, so far as evidence shows, is very shortly after emergence. The average length of adult life is between 3 and 5 months at summer temperatures; longer than that if temperatures induce hibernation. Seven out of 17 adult specimens collected in the field on September 3, 1937, the age of which was unknown, were still actively laying eggs on January 1, 1938 at a constant temperature of 75° F.

3. Feeding habits. Adults seize their prey by creeping upon it, then with their two powerful jaws crush the exoskeleton. They have some difficulty unless the host can be cornered against something solid as in a bark crevice. Once the adult has gained its prey, the wing covers are torn loose from the host and the body juice and soft contents completely devoured, while nothing is left excepting the wings, wing covers, appendages and exoskeleton. In from 3 to 5 minutes an adult mountain pine beetle is so reduced. As many as 15 mountain pine beetles are consumed in 24 hours by one large Temnochila adult.

Enoclerus sphegeus

Seasonal cycle.

One generation is produced each year. Adults are present during the fall, winter, and spring months on trees containing the overwintering broods of the mountain pine beetle. Eggs are laid during the warm months of these seasons, most of which are deposited in the fall. The larvae feed upon the mountain pine beetle broods and reach maturity and migrate to the base of overwintering trees at the time emergence of the mountain pine beetle begins, late in the spring and early summer. Pupal cells are

constructed in the outer bark of the root collar in a narrow band from 4 to 6 inches wide below the duff level at the base. Following a period of aestivation, pupation occurs, and adults emerge the following fall. Further details on each stage of development are presented.

Eggs.

Eggs are laid in groups of from 2 to 8 or more, beneath bark scales, in crevices, and near the entrance holes of the mountain pine beetle. They are elongate, 3 to 4 mm. long and ½ mm wide; pointed both ends; both ends white; middle portion pinkish or orange. The incubation period is 10 to 14 days.

Larvae.

1. Overwintering. Most of the larvae develop during the late fall, winter, and spring months. By the time new D. monticolae of the overwintering brood have begun to emerge, the larvae of the E sphegeus, then fully grown, begin to migrate toward the base of the infested tree. Withcomplete abandonment by D.m. adults very few E. sphegeus larvae are left beneath the bark. During 1937 the heaviest migration period occurred during the month of July. Each larva migrates to a definite location at the base of the abandoned tree, namely to the root collar, a narrow band from 4 to 6 inches wide surrounding the trunk, lying immediately below the surface and adjacent to the duff layer. Here, pupal cells are constructed in the outer bark, very close to the surface. Each cell is lined with a silvery-white secretion. With the completion of cells, each larva assumes a position with the head and prothoracic portion bent ventrally against the abdomen. An aestivation or resting period then ensues, which lasts from 20 to 30 days before pupation. A portion of the larvae (possibly 30 to 40 %) do not pupate, but remain in the cells throughout the summer, fall and winter months, pupating the following spring.

2. Summer. A small brood of larvae is developed in trees containing the summer broods of D. monticolae. Although this brood is so small it is of relatively little significance, it is still worth considering in the life history of E. sphegeus. This brood originates from eggs laid by parent adults, a few of which still survive, following the attack and establishment of the first new summer D.m. broods. Larvae established at this time develop to maturity by the first to middle of August, and migrate.

Pupae.

Following aestivation, pupation takes place within the lined cells. The pupal period lasts from 10 to 25 days, depending on the prevailing temperatures.

Adults.

Adults are most prevalent during the late fall, winter and spring months. Emergence begins late in August, but only a few come out. By the end of September, emergence of adults is common. Although never thoroughly checked, evidence from observations of previous seasons

indicate that the greatest emergence of adults occurs during October, April and May.

Mating pairs of adults are found commonly on warm days during the spring months. The oviposition period begins shortly following sexual maturity in the fall. This is borne out by experiments carried on at Berkeley where it was found that adults placed in cages containing logs infested with new broods of D. monticolae during October produced a brood of 3/4 to mature larvae by January, 1938. Owing to warmer temperatures at Berkeley the larvae continued to develop. The temperatures prevailing in the field would induce hibernation.

During 1937, adults were occasionally found up to the first of July. Almost complete disappearance of adults followed after July 7.

Feeding habits of adults.

The adult seizes its prey by pouncing upon it from either front or rear. Then by grasping the host with the two fore pairs of legs and using the rear pair for secure footing, the host is manipulated quickly so that the ventral surface is held securely facing the mandibles of E. sphegeus. Feeding immediately begins, always on the soft tissue between the head and prothorax or between pro and mesothorax. The head is shortly severed from the body, and feeding is continued on the juices and soft portions of the body cavity from the anterior to the posterior portion. Wings, wing covers, and appendages are torn off, and the body segments are torn apart. Only fragments of the host are left after 20 minutes to half an hour of feeding. In a semi-starved condition, an adult E. sphegeus will eat from 3 to 4 D. monticolae adults in a short period. With an abundance of host food, the average consumption is found to be one D.m. adult in a 24 hour period.

Statistics on migrated individuals.

Periodic sampling from different trees during July and August yielded important information on the number and stage of development. Statistics taken from this sampling are summarized in table 2.

Table 2.
Number of each brood stage found in trees sampled during July and August

Tree No.	Date-1937	Bark area, sq.ft.	Larvae	Pupae	Adults (new)
37/21	7/16	.04	50	1	0
OW/1	7/27	.70	115	5	2
OW/2	7/28		188	19	1
OW/3	7/30	3.19	120	26	1
OW/4	8/2	2.00	19	1	0
OWTK/5	8/2	7.50	17	1	0
OW/6	8/3	16.00	295	1	0
OW/7	8/3	3.33	19	1	0
OW/8	8/5	4.16	37	1	0
OW/9	8/20	3.33	15	22	24
OW/11	8/20	4.00	57	190	17

Considerable variation in number of individuals per tree is evident, and it is quite likely this is due to the relative success of mountain pine beetle broods. Advancement in stages of E. sphegeus was evident by the end of August.

BIOLOGICAL CONTROL EXPERIMENT

Methods.

In this experiment the primary objective was to find out the effect of each predator in reducing the mountain pine beetle brood under controlled conditions. This was done by setting up a series of green sugar pine logs each inside of an insect tight cage (see photo) made up of muslin tacked to a wood frame. Mountain pine beetle adults were admitted to attack the logs at the rate of 20 per square foot. Within 24 hours, following the introduction of D. monticolae adults, a given number of each predator was introduced, each species in separate cages. One log in which no predators were introduced, was used as a check.

A repetition of the experiment was set up at the same time on living trees, having similar conditions of growth and crown classification. Cylinder type cages enclosing from 8 to 10 feet of the lower bole were constructed out of 20-mesh copper screen. To insure against outside contamination by migration of insects beneath the phloem, the trees caged were girdled to the sapwood above and below the caged area, then the screen of the cylinder was drawn tightly against a layer of cotton tacked to the girdled areas.

Very little information was found out on Enoclerus sphegeus. This was due probably to one of two causes; either the adults used were too old, or else they did not respond normally to cage conditions. There is good reason to believe the adults used were too old, since they were collected shortly before the disappearance of adults in the field.

The set up for this experiment was made between June 7 and 10, 1937. Analyses were made between August 24 and 30, 1937 when the adult D. monticolae of the new brood had begun to emerge.

Results.

In making the analyses, a complete count was made on the D. monticolae brood and the number of predators present,,by removing the bark and shaving it down to expose hidden individuals. The results are summarized in tables 3,4, and 5.

Table 3.
Comparative control of D. monticolae in logs and standing trees

Green logs.

Log No.	Bark area sq.ft.	Predator used	No. of predators introd.	No. of D.m. attacks	D.m. brood Total	D.m. brood per sq.ft.	No. of predator larvae	% control
1	4.75	Check	0	30	389	81.9	0	0
3	4.36	T.v.c.	14	30	35	8.0	13	91
4	3.99	T.v.c.	20	21	48	12.0	6	88
5	4.80	E.spheg.	25	24	311	64.7	3	20
			Standing Trees					
1	12.00	Check	0	102	1,217	101.4	27	0
2	14.00	T.v.c.	50	114	714	51.0	80	42

The results shown by Table 3 and Figure 3, indicate the influence of each predator in reducing D. monticolae brood in the logs. The great reduction by Temnochila hardly seems justified, however, if this predator is considered the only control factor, since so few larvae were found at the time of analysis. There was some indication of the larvae having migrated before analyses were made, with evidence shown by trails in the borings at the base of logs 3 and 4. It was possible for the larvae to have escaped in cracks beneath the cage.

The presence of considerable fungus development beneath the bark of all logs may have reduced the brood somewhat. This facdor which was evident to the same extent in the check as in the others, did not appreciably affect the brood in the check. Hence, the predators alone must have been responsible for the reduction.

In considering the standing trees, there is noted also an appreciable reduction of brood in the tree containing Temnochila, compared with the check. The results, however, are not in line with those in the log test. This is partly explained by the fact that in spite of every precaution to keep predators outside the check cage, a few entered and established broods. A total number of 27 predators was found composed of 3 Thanasimus lecontei larvae, 1 T. lecontei pupa, 15 T.v.c. larvae, 7 Nudobius adults and one dipterous larva. These undoubtedly reduced the brood in the check and thus limited its value as a check tree.

Owing to improper selection of the tree on which E. sphegeus adults were caged, the results were not comparable with the check or with T.v.c., hence were omitted. This tree successfully resisted all except a small patch of D.m. attacks.

Table 4
Relation between D.m. parent adults and brood present.

Logs

Log #	No. parents	Tot.brood	Ratio	Control factor
1	115	389	1-3.38	Check
3	108	35	1- .32	T.v.c.
4	95	48	1- .50	T/v/c.
5	120	311	1-2.59	E. sphegeus
		Trees		
1	460	1,217	1-2.64	Check
2	560	714	1-1.27	T.v.c.

This table shows a very definite reduction of brood in relation to parents where T.v.c. were concerned in the logs and a slight increase when they were concerned on the standing tree. A decided increase was indicated in both the checks and in the logs containing E. sphegeus.

E. sphegeus as a control factor in log 5 was negligible. This result is hardly comparable with the others, since it is believed the adults used were spent, i.e., their eggs had been laid elsewhere before being used in the test. There is also a possibility that they did not respond normally to cage conditions.

Table 5
Stages of D.m. brood at the time of analysis.
Logs

Log No.	Larvae	Pupae	Adults (new)	Total
1	110	18	261	389
3	10	3	22	35
4	22	2	24	48
5	88	12	211	311
		Trees		
1	141	51	1,025	1,217
2	44	34	636	714

It is readily seen that the broods of D.m. were mature at the time of analyses. Although there was the possibility of still further reduction of brood, the results obtained are sufficient for comparison.

Need for more control experiments.

Biological control experiments should be continued to further substantiate these preliminary results, especially utilizing Temnochila. One factor which must be eliminated, or at least reduced, is the development of fungi. While the results of the experiment concluded do not show fungi to be important, there is still a question. In future tests, greater care should be exercised in providing free circulation of air to the logs, allowing them to dry out somewhat during the course of the experiments.

The use of sexually mature predators of a known age is essential, and the proportion of sexes should be known. Such practice will reduce the possibility of failures on account of sexual immaturity or infertility.

FACTORS IN BIOLOGICAL CONTROL

Number of host individuals preyed on.

Preliminary data on this point have been secured for Temnochila larvae and adults, with a small amount of information on E. sphegeus adults. Table 6, which summarizes the tests with 4 Temnochila larvae, indicates that between 90 and 125 mountain pine beetle larvae may be eaten during the period of development for one individual.

Table 6.
Number of D. monticolae brood eaten by Temnochila larvae.

T.v.c. No.	No. of D.monticolae eaten: larvae	pupae	adults	Period of feeding: Date, 1937	Days	Av. daily consumption
1	25	36	1	7/22-9/14	54	1.14
2	26	14	1	7/22-9/10	50	.82
3	34	22	1	7/22-9/14	54	1.05
4	43	6	0	7/22-9/14	54	.90

Specimens numbered 1,2 and 3 were ½ grown at the beginning of the test and had advanced to 3/4 grown at the end. Specimen number 4 was newly hatched at the beginning of the test and advanced to ½ grown at the end.

Tests carried on in the laboratory at Berkeley, California with 11 T.v.c. adults for a 10-day period between October 15 and 25, 1937 resulted in an average daily consumption of 1.9 D. monticolae adults. Among individuals there was a variation in number from 1 to 15 D.m. adults eaten during 24 hour periods.

Preliminary tests indicate that E. sphegeus adults do not feed upon as many D. monticolae adults as T.v.c. adults do. The average daily consumption by 7 adults between Nov. 15 and 22, 1937 amounted to .83 D.m. adults.

Fecundity and longevity of adults.

The adult life period of Temnochila virescens varies according to the prevailing temperatures of its environment. Of 17 adults kept at a constant temperature of 75° F. in the laboratory from October 19, 1937, 3 were remaining and actively laying eggs on January 25, 1938. These adults were collected in the field on September 3, 1937 and placed in cold storage at 36° F. from that date until October 19, 1937. The period between emergence from the pupal stage and the date of collection is unknown. The 3 remaining adults were known to be at least nearly 5 months old. Nine of the 17 adults were females. A total number of 709 eggs was collected from this set between October 19, 1937 and February 2, 1938.

Dissection of 5 unfertilized sexually mature female Temnochila adults to determine the reproductive capacity yielded an average of 314 eggs per individual. This potential is equal to or slightly greater than D. monticolae.

ARTIFICIAL CONTROL IN RELATION TO SEASONAL CYCLE OF PREDATORS

Burning method.

This method of bark beetle control in sugar pine stands must necessarily be undertaken during the winter and spring when the dangers from destructive fires are absent. Such practice obviously destroys the beneficial insects, among which Enoclerus sphegeus, for the most part in the larval stage, has no chance of escape. Temnochila virescens, as indicated by this preliminary investigation are not numerous enough in association with overwintering broods of the mountain pine beetle to warrant considering in the burning method of control.

Suncuring.

The suncuring method of control which is applicable during the warm, dry summer season is also destructive to predators lying within the bark. Tests carried on during a small suncuring project at Signal Peak* on the Sierra National Forest during 1937, indicated that Temnochila virescens, the most prevalent predator associated with summer broods of the mountain pine beetle, do not escape from the treatment. Enoclerus sphegeus larvae are not numerous enough in association with summer broods to be considered worth protecting.

POSSIBILITIES OF BIOLOGICAL CONTROL

Before any definite plan regarding biological control of the mountain pine beetle in sugar pine can be put into practice, a thorough investigation should be undertaken to determine:

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*Struble, G. R. Signal Peak Insect Control Project - Sierra National Forest. Berkeley, California, Nov. 5, 1937.

1. Whether it is possible to modify artificial control practice to prevent the destruction of predators, thus giving them a chance to act as a supplemental control factor.

2. Whether biological control through the protection and artificial propagation of native predators is shown to have advantages over the practice of artificial control.

3. Whether it is possible or economically feasible to maintain populations of predators during endemic years when the natural host is scarce, through the practice of rearing them on foreign host material.

4. Whether the native predators are specific enough to be consistently effective in controlling the mountain pine beetle.

SUMMARY

Studies were carried out during 1937 near Wawona, California on the two most important coleopterous predators of the mountain pine beetle in sugar pine stands. These are the blue-green trogositid, Temnochila virescens and the red-bellied clerid Enoclerus sphegeus. The most important points found in connection with these two insects are as follows:

1. Among overwintering broods of the mountain pine beetle, E. sphegeus was the most prevalent of all coleopterous predators found. T. virescens was found occasionally, but could not be considered as an important biological control factor.

2. Among summer broods of the mountain pine beetle, T virescens was found to be most common, while the presence of E. sphegeus larvae was rare.

3. The seasonal history and habits of both predators were determined as follows:

T. virescens. One generation is produced each year with overwintering stages mainly as adults and some larger larvae. Eggs are laid in bark crevices, bark plates, etc., of infested trees during the spring and summer months.

E. sphegeus. One generation is produced each year, a portion of which overwinters as larvae during the second winter. Eggs are laid in fall and spring months. Mature larvae migrate to the base of abandoned trees to aestivate and pupate. Adults emerge in the fall and spring.

4. A control experiment carried out with each predator to determine the effect against mountain pine beetle broods resulted in some interesting points.

a. *Temnochila virescens* was shown to be highly effective against mountain pine beetle broods artificially established in logs. In two logs tested, the control amounted to 99 and 88 percent compared to a third check log.

b. Compared to *Temnochila*, *E. sphegeus* showed very little effect on the control of mountain pine beetle in logs. The control in one log amounted to 20 percent.

c. Control of *D. monticolae* artificially established in a standing tree by *Temnochila* amounted to 42 percent compared to a check tree in which no predators were introduced. This result was modified by contamination by predators gaining entrance to the check tree.

5. Further studies on these two predators are essential to determine their relative value in biological control and the feasibility and possibility of protecting them in the practice of regular artificial control measures.

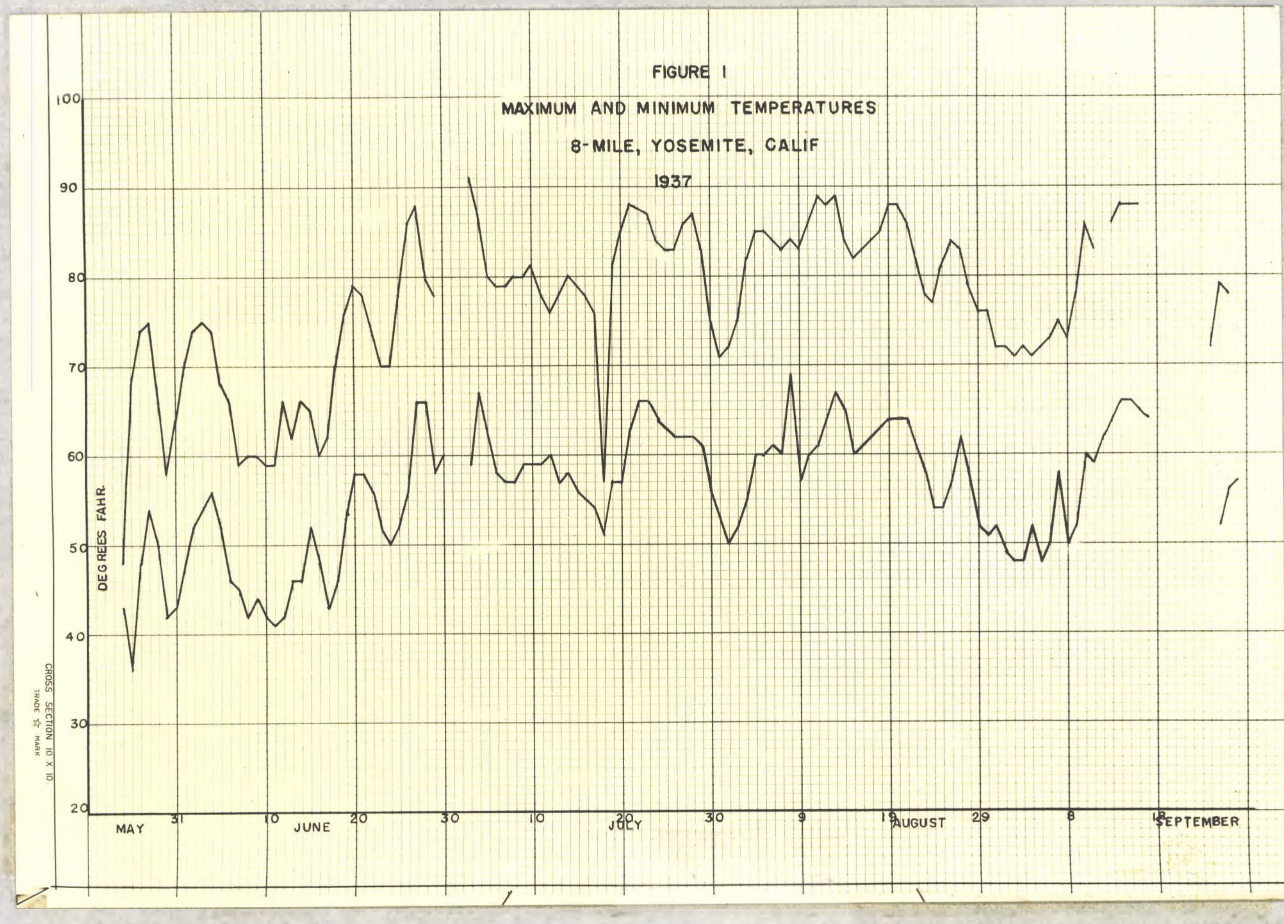


Figure 1 (9952). Air temperatures recorded at experimental field base. 1937. Photo by J. E. Patterson.

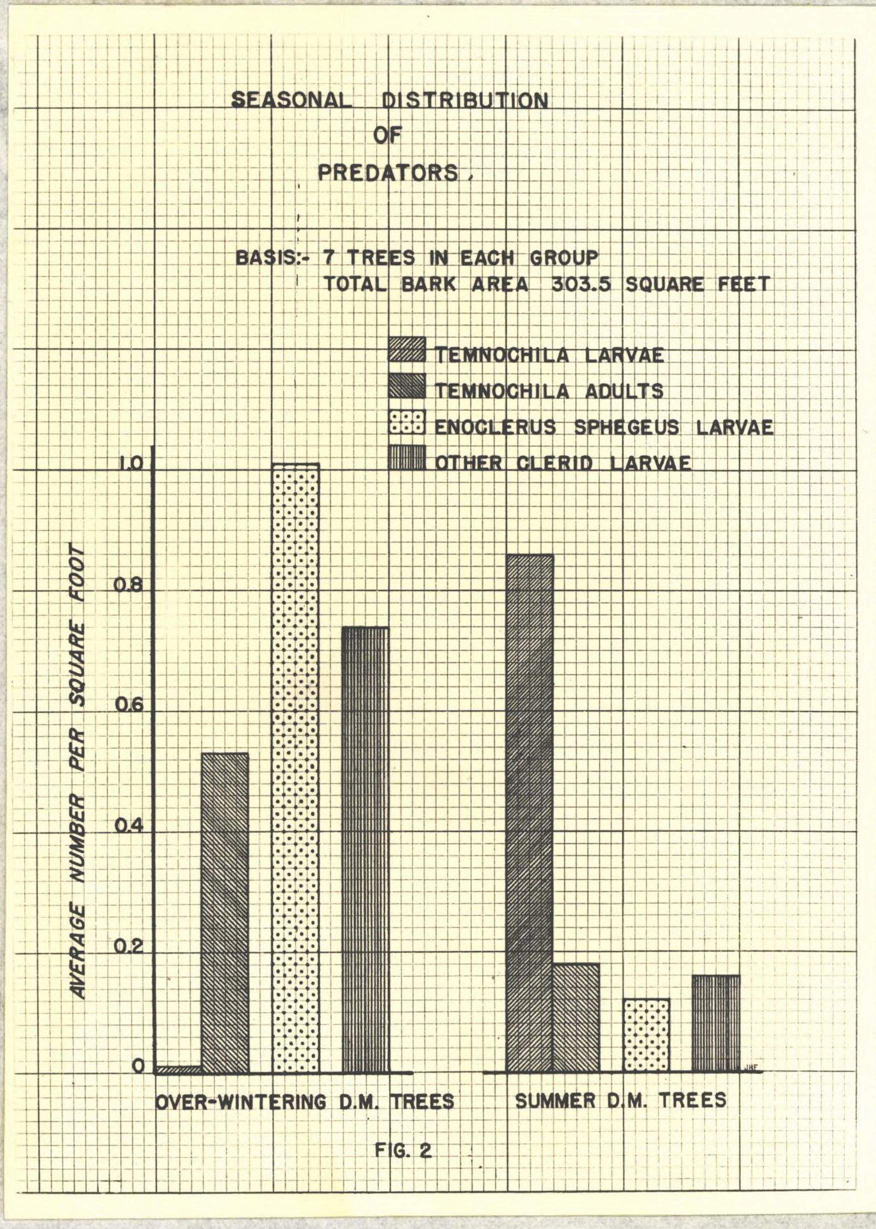
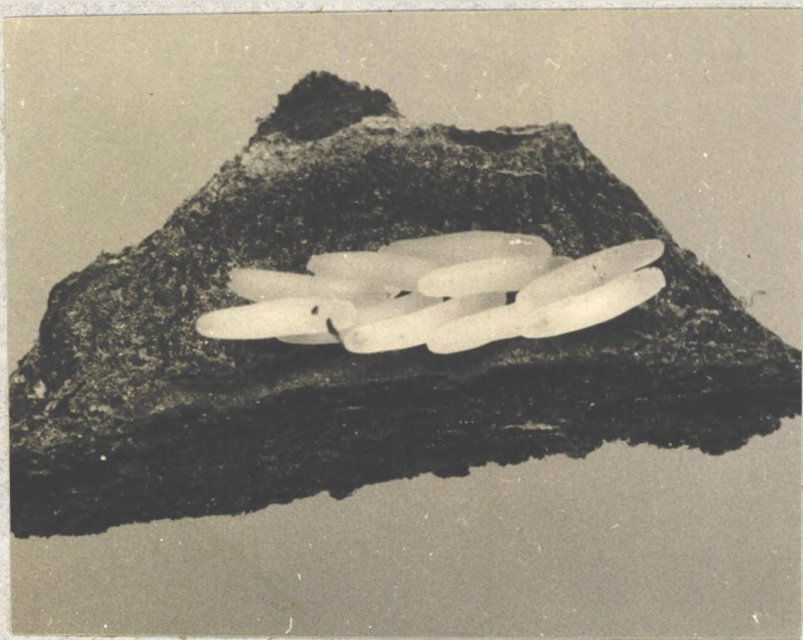


Figure 2 (9953B). Seasonal distribution of predators in sugar pines infested by D. monticolae. Photo by J. E. Patterson.



#9951. Eggs (enlarged x7). Bark scale lifted up revealing a cluster of 10 eggs. Photo by J. E. Patterson.

#9954A. Larva. Habit on inner surface of sugar pine bark infested by the mountain pine beetle. Photo by J. E. Patterson. (Slightly enlarged.)

#9955. Pupa (slightly enlarged). Habit in cell constructed in phloem layer, inner bark surface of sugar pine infested by D. monticolae and flatheads. Photo by J. E. Patterson.

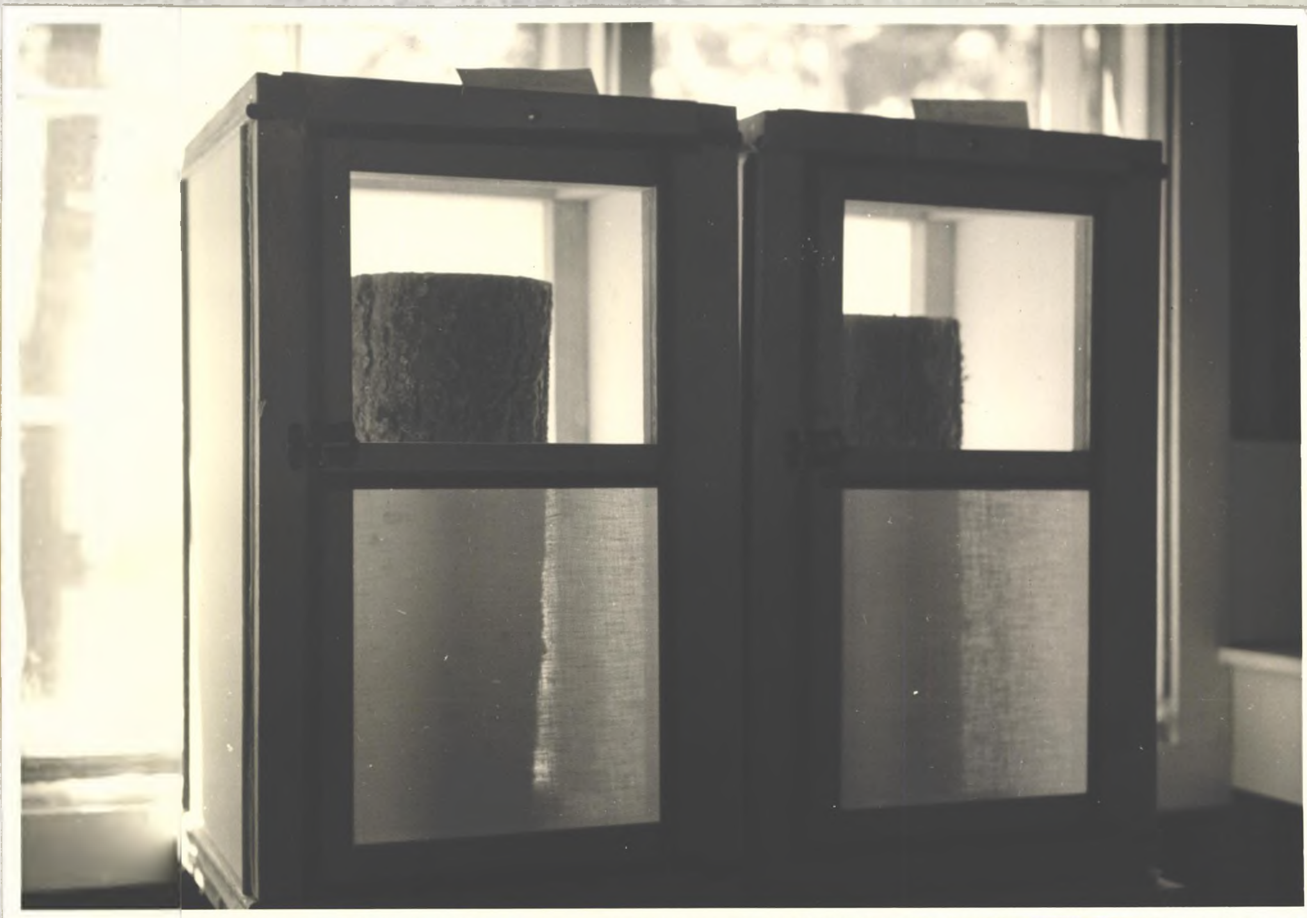
#9963A. Adult (enlarged X4). Approaching mountain pine beetle adult on bark. Typical pose assumed before crushing its prey. Photo by J. E. Patterson.

#9957B. Eggs. (Enlarged X7). Bark scale removed exposing a cluster of eggs packed tightly in bark crevice. Photo by J. E. Patterson.

#9956A. Larva (enlarged X2) on inner surface of sugar pine bark, feeding on mountain pine beetle larva. Photo by J. E. Patterson.

#9956B. Pupa in lined cell found in outer bark at base of large sugar pine killed by D. monticolae. A cell in cross section shows up at the lower right. Photo by J.E. Patterson.

#9965A. Adult stalking prey. (Enlarged X3½) Typical position in approaching D. monticolae adults prior to manipulating them in position for feeding. Photo by J. E. Patterson.



#10034. Muslin type cages with glass windows, enclosing green sugar pine logs used in testing the effectiveness of predators in the control of the mountain pine beetle. (Photo Original.)

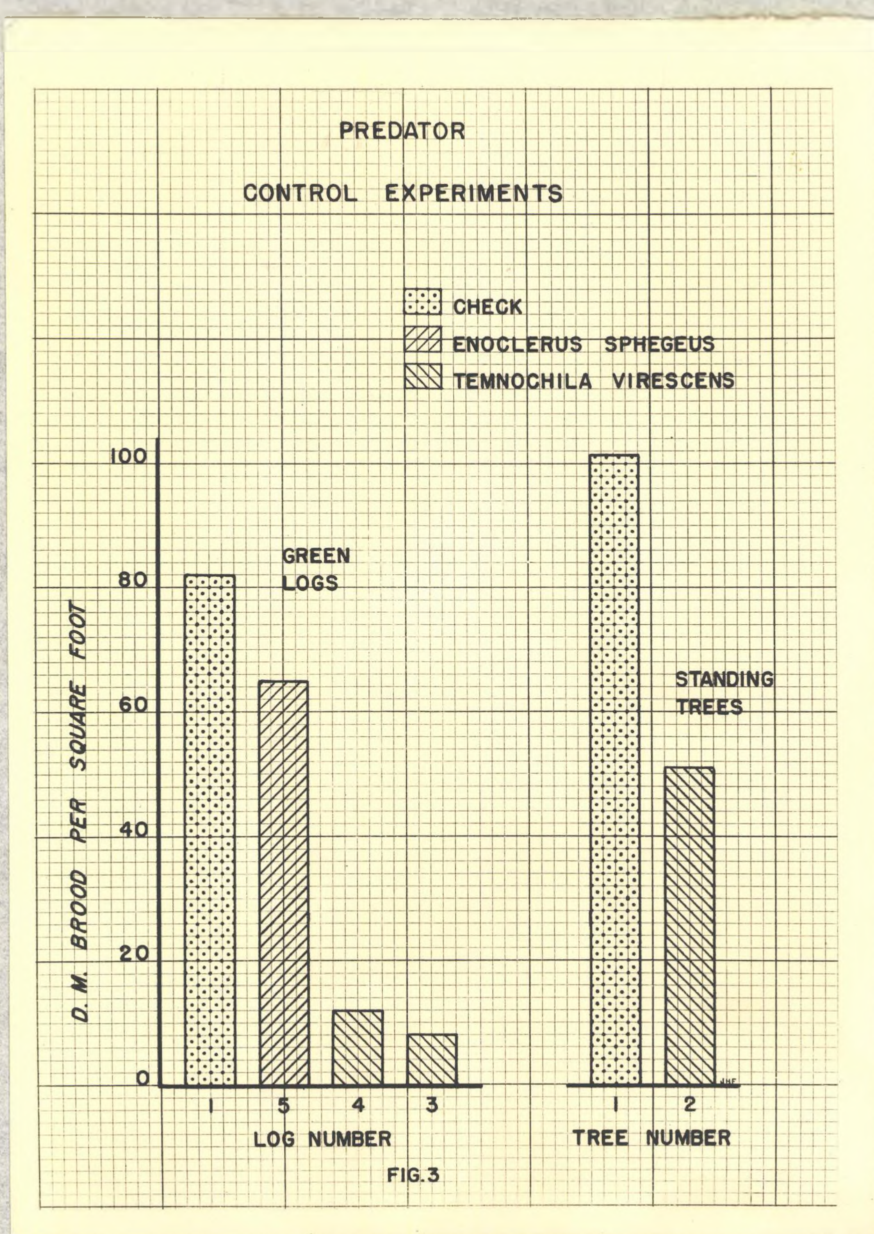


Figure 3. (9953A) Comparative effectiveness of T. virescens and E. sphegeus in the control of the mountain pine beetle. Photo by J. E. Patterson.